The Yield Curve as an Accurate Predictor of Economic Crises

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Class: Data Bootcamp

Introduction

The Yield Curve, measured as the difference in interest rates between short-term and long-term Treasuries, has long been thought of as a way to determine future economic conditions. More specifically, when the curve inverts (short-term Treasuries yield more than long-term Treasuries), it is interpreted as a sign that an economic recession will soon hit. This project will use data from FRED (https://fred.stlouisfed.org) containing information on the Yield Curve and different economic indicators to gauge whether the Curve has accurately predicted crises.

This project will contain the following three sections:

1. Data on the following economic indicators from January 1982 to April 2019: Civilian Unemployment Rate, Motor Vehicle Retail Sales (Domestic Autos), Industrial Production Index, and the Effective Federal Funds Rate. Here the project will use statistics (e.g. growth rates, normalizing, etc.) on the indicators to find dates when the the indicators reflected recessionary periods.

1. Graphics plotting the four indicators and labels reflecting Yield Curve inversions. Ideally the dates of inversion are soon followed by periods where the economic indicators show an economic decline. This would illustrate that the Yield Curve serves as a predictor of economic crises in the U.S.

1. Five graphics showing normalized numbers as well as difference in numbers for the economic indicators in order to evaluate how they behave following an inversion in the Yield Curve. Each individual graphic will represent the five times it has inverted from 1982 to 2007. Although the Curve did also invert in 2019, I will be excluding this date since the inversion happened late March and there is not much data on the economic indicators thereafter.

Data Report

As already noted, the data on the Yield Curve and the four economic indicators will be sourced from FRED for a 37 year period. The variables are defined in the following way by FRED:

- Yield Curve (https://fred.stlouisfed.org/series/T10Y3M): "spread between 10-Year Treasury Constant Maturity and 3-Month Treasury Constant Maturity".
- Civilian Unemployment Rate (https://fred.stlouisfed.org/series/UNRATE): "The unemployment rate represents the number of unemployed as a percentage of the labor force. Labor force data are restricted to people 16 years of age and older, who currently reside in 1 of the 50 states or the District of Columbia, who do not reside in institutions (e.g., penal and mental facilities, homes for the aged), and who are not on active duty in the Armed Forces."
- Motor Vehicle Retail Sales (Domestic Autos) (https://fred.stlouisfed.org/series/DAUTOSA): "Autos are all passenger cars, including station wagons. Domestic sales are all United States (U.S.) sales of vehicles assembled in the U.S., Canada, and Mexico."
- Industrial Production Index (https://fred.stlouisfed.org/series/INDPRO): "The Industrial Production Index (INDPRO) is an economic indicator that measures real output for all facilities located in the United States manufacturing, mining, and electric, and gas utilities (excluding those in U.S. territories)."
- Effective Federal Funds Rate (https://fred.stlouisfed.org/series/FEDFUNDS): "The federal funds rate is the interest rate at which depository institutions trade federal funds (balances held at Federal Reserve Banks) with each other overnight."

Now I will run through the process to grab the files using Datareader and create two dataframes: one with the Yield Curve data on it from January 1982 to April 2019 and another with all the economic indicators for the same dates.

Packages Needed

In [2]:
```
import pandas as pd

import matplotlib.pyplot as plt

import datetime as dt

import numpy as np

from pandas_datareader import data
```

Grabbing Data Using Datareader

In [3]:
```
codes1 = ["T10Y3M"]

yield_curve = data.DataReader(codes1, "fred", 1982)
```

In [4]:
```
codes2 = ["UNRATE", "DAUTOSA", "INDPRO", "FEDFUNDS"]

economic_indicators = data.DataReader(codes2, "fred", 1982)
```

Renaming For Convenience

In [5]:
```
yield_curve.rename(columns = {'T10Y3M': 'Yield'}, inplace = True)
economic_indicators.rename(columns = {'UNRATE': 'Unemployment_Rate',
                                      'DAUTOSA': 'Vehicle_Sales',
                                      'INDPRO': 'Industrial_Production'
,
                                      'FEDFUNDS': 'Fed_Funds'}, inplace
= True)
```

Dates With Curve Inversion

In [6]:
```
yield_curve_inversion = yield_curve.loc[yield_curve['Yield'] < 0]
```

In [7]:
```
yield_curve_inversion.head()
```

Out[7]:

DATE	Yield
1982-02-01	-0.19
1982-02-02	-0.02
1982-02-08	-0.16
1982-02-10	-0.07
1982-02-11	-0.35

Grouping By Year and Month

In [8]:
```
yield_curve_inverted = yield_curve_inversion.groupby(
    [yield_curve_inversion.index.year,
     yield_curve_inversion.index.month])
```

In [9]:
```
inverted_yield_curve = yield_curve_inverted.agg({"Yield": "mean"})
```

Finalized Dataframes

In [10]:
```
inverted_yield_curve
```

Out[10]:

		Yield
DATE	**DATE**	
1982	**2**	-0.357500
1989	**3**	-0.010000
	5	-0.163333
	6	-0.157273
	7	-0.170625
	8	-0.105625
	10	-0.096667
	11	-0.078947
	12	-0.066875
1998	**9**	-0.062500
	10	-0.070000
2000	**4**	-0.045000
	7	-0.121333
	8	-0.451304
	9	-0.376000
	10	-0.556190
	11	-0.639048
	12	-0.696500
2001	**1**	-0.269231
	2	-0.030000
2006	**1**	-0.023333

	2	-0.038000
	3	-0.010000
	7	-0.058000
	8	-0.213913
	9	-0.211000
	10	-0.317143
	11	-0.478095
	12	-0.408500
2007	**1**	-0.345714
	2	-0.440526
	3	-0.515455
	4	-0.312857
	5	-0.143500
	7	-0.088750
	8	-0.110000
2019	**3**	-0.038000
	5	-0.030000

As we can see above, there were six inversions from 1982 to 2019. However, as mentioned before, 2019's inversion will be excluded. The first inversion of interest ocurred in 1982, the second in 1989, the third in 1998, the fourth in 2000-2001, and the fifth in 2006-2007.

In [11]:
```
economic_indicators.head()
```

Out[11]:

DATE	Unemployment_Rate	Vehicle_Sales	Industrial_Production	Fed_Funds
1982-01-01	8.6	445.7	50.3043	13.22
1982-02-01	8.9	520.7	51.3016	14.78
1982-03-01	9.0	489.0	50.9104	14.68
1982-04-01	9.3	455.9	50.4627	14.94
1982-05-01	9.4	531.9	50.1380	14.45

Above, we can see that the monthly numbers for the four economic indicators we are interested in from 1982 to 2019 are found within this dataframe. With it we can perform different analysis/statistics and create visuals.

Statistics

One useful way to analyze the economic indicators is to view the montly growth rates.

In [12]:
```
economic_indicators['UR_Growth_Rate'] = economic_indicators[
    'Unemployment_Rate'].pct_change()
economic_indicators['VS_Growth_Rate'] = economic_indicators[
    'Vehicle_Sales'].pct_change()
economic_indicators['IP_Growth_Rate'] = economic_indicators[
    'Industrial_Production'].pct_change()
economic_indicators['FF_Growth_Rate'] = economic_indicators[
    'Fed_Funds'].pct_change()
```

In [13]:
```
economic_indicators.head()
```

Out[13]:

DATE	Unemployment_Rate	Vehicle_Sales	Industrial_Production	Fed_Funds	UR_Growth_Rate
1982-01-01	8.6	445.7	50.3043	13.22	NaN
1982-02-01	8.9	520.7	51.3016	14.78	0.034884
1982-03-01	9.0	489.0	50.9104	14.68	0.011236
1982-04-01	9.3	455.9	50.4627	14.94	0.033333
1982-05-01	9.4	531.9	50.1380	14.45	0.010753

Before proceeding, it would be good to conduct a preliminary check on the relationship between the Yield Curve and the U.S. economy. To do this, I will create a dataframe which contains only the periods in which the growth rates were positive for the Unemployment Rate, and negative for Vehicle Sales, Industrial Production, and the Effective Fed Funds Rate. It is important to note why for the Unemployment Rate the positive change is what we are after and the negative change for the other three indicators. When the economy faces a crisis, unemployment spikes. Therefore, we care about the dates in which the Unemployment Rate starts growing. For Vehicle Sales and Industrial Production, we are after a negative growth rate because that is when less vehicles and industrial products are made and sold, which happens during an economic decline. For the Fed Funds, we are also after the negative growth number because the Federal Reserve lowers the rate whenever the economy is tanking in an effort to stimulate it.

In [14]:
```
negative_impact = economic_indicators.loc[
    (economic_indicators['UR_Growth_Rate'] > 0) &

    (economic_indicators['VS_Growth_Rate'] < 0) &

    (economic_indicators['IP_Growth_Rate'] < 0) &

    (economic_indicators['FF_Growth_Rate'] < 0)]
```

In [15]:
```
negative_impact
```

Out[15]:

DATE	Unemployment_Rate	Vehicle_Sales	Industrial_Production	Fed_Funds	UR_Growth_Rate
1982-03-01	9.0	489.000	50.9104	14.68	0.011236
1982-06-01	9.6	427.500	49.9692	14.15	0.021277
1982-10-01	10.4	444.000	48.7874	9.71	0.029703
1984-10-01	7.4	633.700	55.9459	9.99	0.013699
1986-02-01	7.2	653.000	56.9344	7.86	0.074627
1990-04-01	5.4	572.200	64.2602	8.26	0.038462
1990-11-01	6.2	530.600	63.5753	7.81	0.050847
1991-01-01	6.4	498.400	62.8852	6.91	0.015873

1991-10-01	7.0	501.600	64.0213	5.21	0.014493
1991-12-01	7.3	499.800	63.6937	4.43	0.042857
1995-07-01	5.7	575.300	73.5664	5.85	0.017857
2001-03-01	4.3	523.800	93.7201	5.31	0.023810
2001-04-01	4.4	515.900	93.4469	4.80	0.023256
2001-06-01	4.5	521.700	92.3208	3.97	0.046512
2001-07-01	4.6	486.400	91.7933	3.77	0.022222
2001-08-01	4.9	472.100	91.6795	3.65	0.065217
2001-11-01	5.5	510.600	90.4860	2.09	0.037736
2008-03-01	5.1	395.800	104.4616	2.61	0.040816
2008-11-01	6.8	283.500	96.0605	0.39	0.046154
2009-01-01	7.8	241.700	91.0373	0.15	0.068493
2009-04-01	9.0	251.700	88.3056	0.15	0.034483
2011-04-01	9.1	365.638	96.1187	0.10	0.011111
2015-01-01	5.7	457.731	105.9806	0.11	0.017857
2016-03-01	5.0	426.853	101.4155	0.36	0.020408

As we can see above, the dates roughly follow the inversions. Although it does not give us much, we can see which periods were marked by the most economic decline. Furthermore, we can see that there is not a moment after the 1998 inversion in which the four indicators showed recessionary numbers. This serves as a signal that the inversion of 1998 was probably an outlier.

To further the analysis, it would be appropiate to find the change in the Unemployment Rate and in the Fed Funds rate from the date an inversion first occured. For Vehicle Sales and Industrial Production, we will normalize the numbers from the same dates onwards.

In [16]:
```
inversion_1982 = pd.DataFrame()
inversion_1982['Unemployment_Rate'] = economic_indicators[
    'Unemployment_Rate'] - economic_indicators.loc[
    '1982-02-01,','Unemployment_Rate']
inversion_1982['Vehicle_Sales'] = economic_indicators[
    'Vehicle_Sales'] / economic_indicators.loc[
    '1982-02-01,','Vehicle_Sales']
inversion_1982['Industrial_Production'] = economic_indicators[
    'Industrial_Production'] / economic_indicators.loc[
    '1982-02-01,','Industrial_Production']
inversion_1982['Fed_Funds'] = economic_indicators[
    'Fed_Funds'] - economic_indicators.loc[
    '1982-02-01,','Fed_Funds']
```

In [17]:
```
inversion_1989 = pd.DataFrame()
inversion_1989['Unemployment_Rate'] = economic_indicators[
    'Unemployment_Rate'] - economic_indicators.loc[
    '1989-03-01,','Unemployment_Rate']
inversion_1989['Vehicle_Sales'] = economic_indicators[
    'Vehicle_Sales'] / economic_indicators.loc[
    '1989-03-01,','Vehicle_Sales']
inversion_1989['Industrial_Production'] = economic_indicators[
    'Industrial_Production'] / economic_indicators.loc[
    '1989-03-01,','Industrial_Production']
inversion_1989['Fed_Funds'] = economic_indicators[
    'Fed_Funds'] - economic_indicators.loc[
    '1989-03-01,','Fed_Funds']
```

In [18]:
```
inversion_1998 = pd.DataFrame()
inversion_1998['Unemployment_Rate'] = economic_indicators[
    'Unemployment_Rate'] - economic_indicators.loc[
    '1998-09-01,','Unemployment_Rate']
inversion_1998['Vehicle_Sales'] = economic_indicators[
    'Vehicle_Sales'] / economic_indicators.loc[
    '1998-09-01,','Vehicle_Sales']
inversion_1998['Industrial_Production'] = economic_indicators[
    'Industrial_Production'] / economic_indicators.loc[
    '1998-09-01,','Industrial_Production']
inversion_1998['Fed_Funds'] = economic_indicators[
    'Fed_Funds'] - economic_indicators.loc[
    '1998-09-01,','Fed_Funds']
```

In [19]:
```
inversion_2000 = pd.DataFrame()
inversion_2000['Unemployment_Rate'] = economic_indicators[
    'Unemployment_Rate'] - economic_indicators.loc[
    '2000-04-01,','Unemployment_Rate']
inversion_2000['Vehicle_Sales'] = economic_indicators[
    'Vehicle_Sales'] / economic_indicators.loc[
    '2000-04-01,','Vehicle_Sales']
inversion_2000['Industrial_Production'] = economic_indicators[
    'Industrial_Production'] / economic_indicators.loc[
    '2000-04-01,','Industrial_Production']
inversion_2000['Fed_Funds'] = economic_indicators[
    'Fed_Funds'] - economic_indicators.loc[
    '2000-04-01,','Fed_Funds']
```

In [20]:
```
inversion_2006 = pd.DataFrame()
inversion_2006['Unemployment_Rate'] = economic_indicators[
    'Unemployment_Rate'] - economic_indicators.loc[
    '2006-01-01,','Unemployment_Rate']
inversion_2006['Vehicle_Sales'] = economic_indicators[
    'Vehicle_Sales'] / economic_indicators.loc[
    '2006-01-01,','Vehicle_Sales']
inversion_2006['Industrial_Production'] = economic_indicators[
    'Industrial_Production'] / economic_indicators.loc[
    '2006-01-01,','Industrial_Production']
inversion_2006['Fed_Funds'] = economic_indicators[
    'Fed_Funds'] - economic_indicators.loc[
    '2006-01-01,','Fed_Funds']
```

Time Delay

Another useful aspect of the data set to look at is how long it took for the four indicators to be negatively impacted since the first date of the Curve's inversion in a given period. This will later be used to plot a bar chart and find the average time the economic decline takes to hit once the Yield Curve has inverted.

In [21]:
```
days_1982_inversion = (negative_impact.index[0] - dt.datetime(1982,2,1
)).days
days_1989_inversion = (negative_impact.index[5] - dt.datetime(1989,3,1
)).days
days_2000_inversion = (negative_impact.index[11] - dt.datetime(2000,4,
1)).days
days_2006_inversion = (negative_impact.index[17] - dt.datetime(2006,1,
1)).days
```

Since there is no date for which the four indicators showed a detrimental impact following the inversion of 1998, it seems to be a false positive and will be excluded it from this calculation.

In [22]:
```
time_delay = pd.DataFrame(index = ['1982', '1989', '2000-2001', '2006-2007'])
time_delay['Days_Since_Inversion'] = (days_1982_inversion,
                                      days_1989_inversion,
                                      days_2000_inversion,
                                     days_2006_inversion)
```

In [23]:
```
time_delay
```

Out[23]:

	Days_Since_Inversion
1982	28
1989	396
2000-2001	334
2006-2007	790

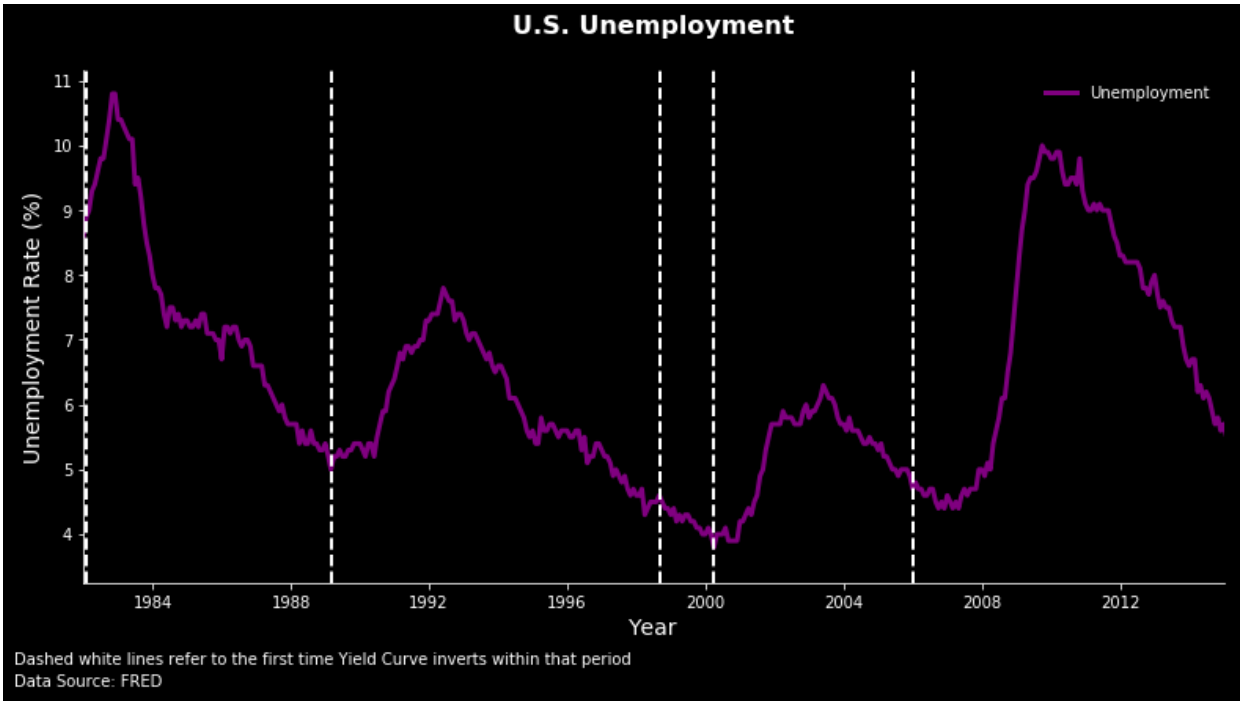
Visuals

Unemployment Rate

In [24]:
```
plt.style.use('dark_background')
```

This changes the default style to one with a dark background.

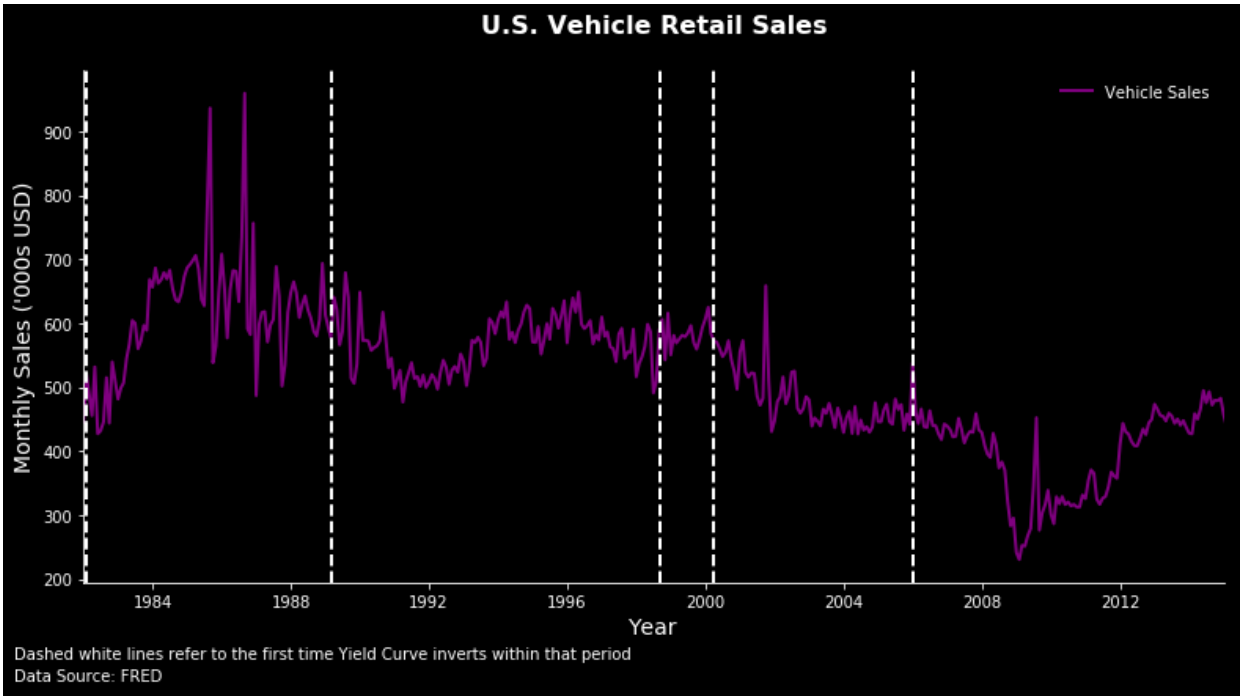
In [25]:
```
fig, ax = plt.subplots(figsize = (13,6))

ax.plot(economic_indicators.index, economic_indicators.Unemployment_Ra
te ,
        color = 'purple', linewidth = 3.0)

ax.set_title("U.S. Unemployment\n", fontsize = 16, fontweight = "bold"
)
ax.set_ylabel("Unemployment Rate (%)", fontsize = 14,)
ax.set_xlabel("Year", fontsize = 14,)

ax.set_xlim(dt.datetime(1982,1,1), dt.datetime(2015,1,1))

ax.spines["right"].set_visible(False)
ax.spines["top"].set_visible(False)

ax.axvline(x= dt.datetime(1982,2,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(1989,3,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(1998,9,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(2000,4,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(2006,1,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)

ax.legend(["Unemployment"],frameon=False)

ax.text(dt.datetime(1980,1,1), 1.65, "Data Source: FRED", fontsize = 1
0)
ax.text(dt.datetime(1980,1,1), 2,
"Dashed white lines refer to the first time Yield Curve inverts within
that period",
        fontsize = 10)

plt.savefig("unemployment_rate.png", bbox_inches = "tight", dip = 3000
)

plt.show()
```



Above we see what was expected: following each inversion, except for 1998's, the unemployment rate spiked up.

Vehicle Sales

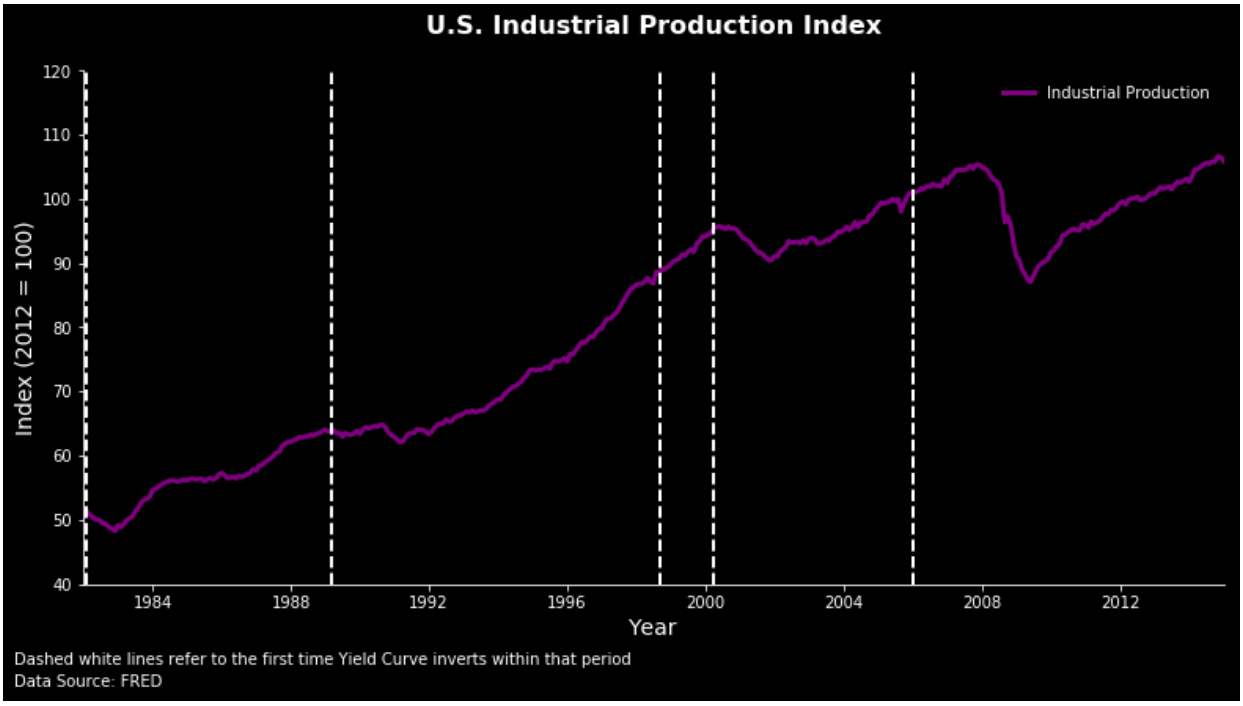
In [26]:
```
fig, ax = plt.subplots(figsize = (13,6))

ax.plot(economic_indicators.index, economic_indicators.Vehicle_Sales ,
        color = 'purple', linewidth = 2.0)

ax.set_title("U.S. Vehicle Retail Sales\n", fontsize = 16, fontweight
= "bold")
ax.set_ylabel("Monthly Sales ('000s USD)", fontsize = 14,)
ax.set_xlabel("Year", fontsize = 14,)

ax.set_xlim(dt.datetime(1982,1,1), dt.datetime(2015,1,1))

ax.spines["right"].set_visible(False)
ax.spines["top"].set_visible(False)

ax.axvline(x= dt.datetime(1982,2,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(1989,3,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(1998,9,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(2000,4,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(2006,1,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)

ax.legend(["Vehicle Sales"],frameon=False)

ax.text(dt.datetime(1980,1,1), 40, "Data Source: FRED", fontsize = 10)
ax.text(dt.datetime(1980,1,1), 75,
"Dashed white lines refer to the first time Yield Curve inverts within
that period",
        fontsize = 10)

plt.savefig("vehicle_sales.png", bbox_inches = "tight", dip = 3000)

plt.show()
```



Although the indicator is very volative, above we can see that at least for the 1989, 2000-2001, and 2006-2007 inversions vehicle sales dropped. As discussed before, 1998 seems to be an exception and for a reason unknown to me vehicle sales did not extensively drop after the 1982 inversion.

Industrial Production

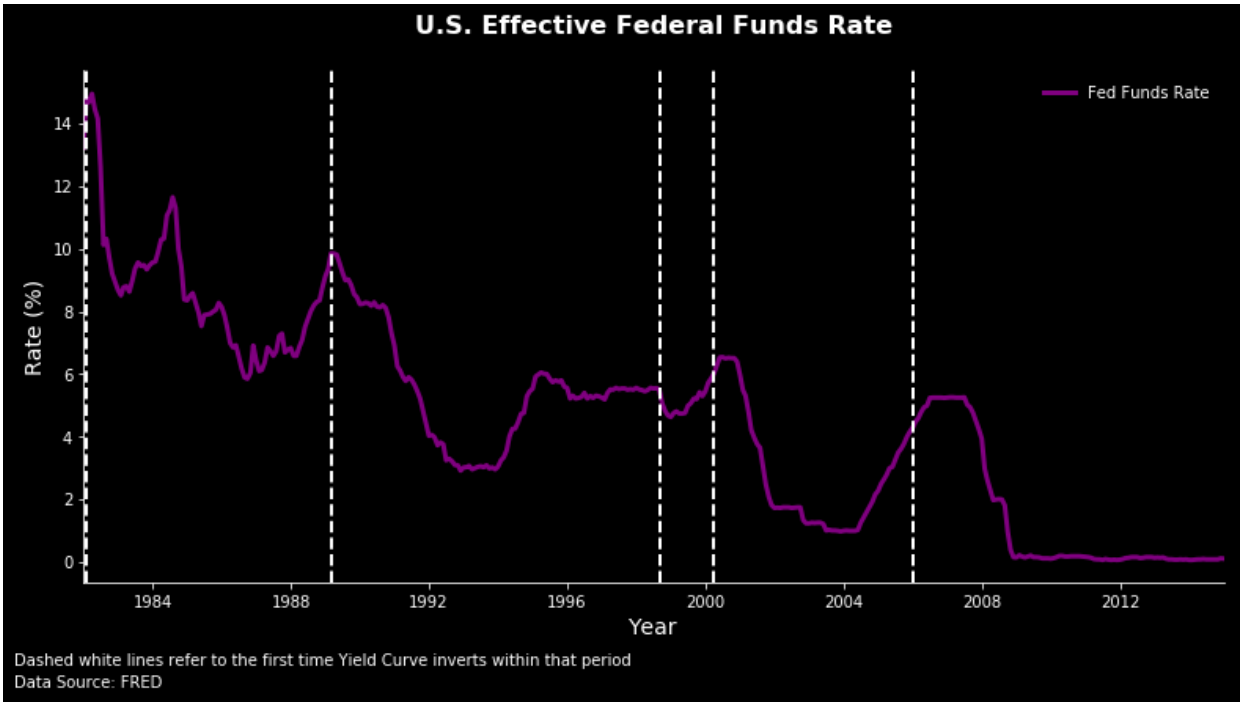
In [27]:
```
fig, ax = plt.subplots(figsize = (13,6))

ax.plot(economic_indicators.index, economic_indicators.Industrial_Prod
uction ,
        color = 'purple', linewidth = 3.0)

ax.set_title("U.S. Industrial Production Index\n", fontsize = 16, font
weight = "bold")
ax.set_ylabel("Index (2012 = 100)", fontsize = 14,)
ax.set_xlabel("Year", fontsize = 14,)

ax.set_xlim(dt.datetime(1982,1,1), dt.datetime(2015,1,1))
ax.set_ylim(40, 120)

ax.spines["right"].set_visible(False)
ax.spines["top"].set_visible(False)

ax.axvline(x= dt.datetime(1982,2,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(1989,3,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(1998,9,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(2000,4,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(2006,1,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)

ax.legend(["Industrial Production"],frameon=False)

ax.text(dt.datetime(1980,1,1), 24, "Data Source: FRED", fontsize = 10)
ax.text(dt.datetime(1980,1,1), 27.5,
"Dashed white lines refer to the first time Yield Curve inverts within
that period",
        fontsize = 10)

plt.savefig("industrial_production.png", bbox_inches = "tight", dip =
3000)

plt.show()
```



Above we see that the Industrial Production Index drops, even if slightly, after every inversion except for the one in 1998. This is what was expected to be seen given that the industrial sector slows down when the economy is performing poorly.

Fed Funds Rate

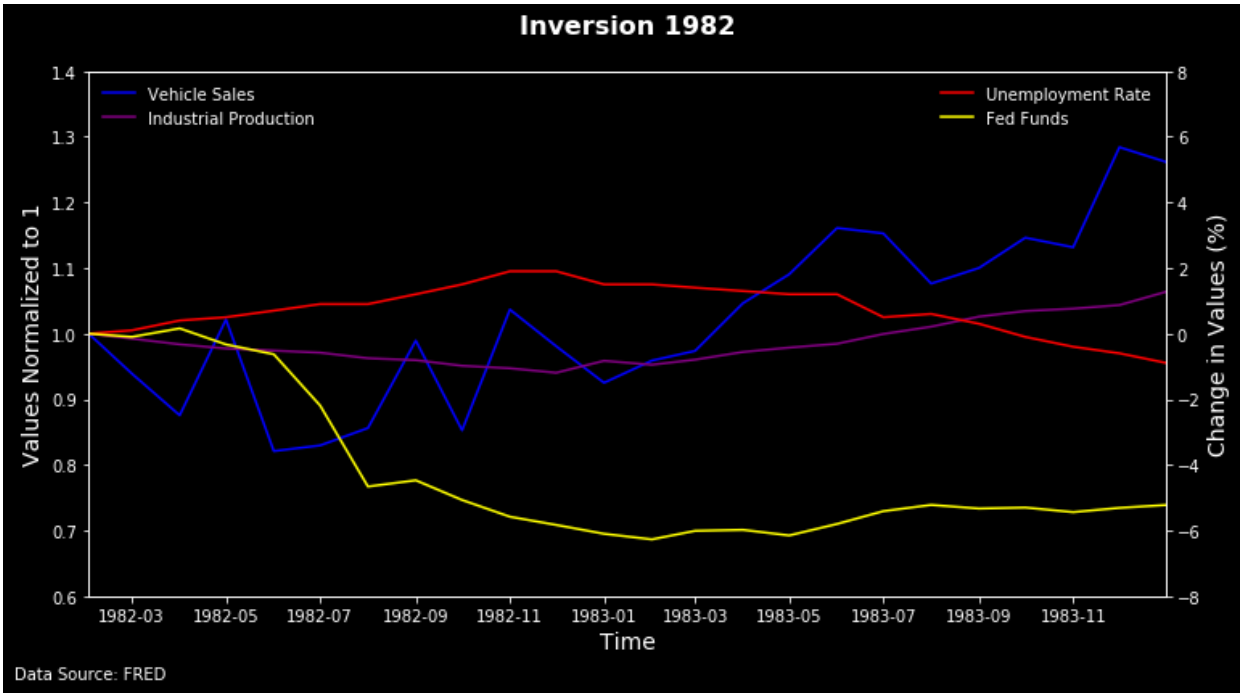
In [28]:
```
fig, ax = plt.subplots(figsize = (13,6))

ax.plot(economic_indicators.index, economic_indicators.Fed_Funds ,
        color = 'purple', linewidth = 3.0)

ax.set_title("U.S. Effective Federal Funds Rate\n", fontsize = 16, fon
tweight = "bold")
ax.set_ylabel("Rate (%)", fontsize = 14,)
ax.set_xlabel("Year", fontsize = 14,)

ax.set_xlim(dt.datetime(1982,1,1), dt.datetime(2015,1,1))

ax.spines["right"].set_visible(False)
ax.spines["top"].set_visible(False)

ax.axvline(x= dt.datetime(1982,2,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(1989,3,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(1998,9,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(2000,4,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(2006,1,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)

ax.legend(["Fed Funds Rate"],frameon=False)

ax.text(dt.datetime(1980,1,1), -4, "Data Source: FRED", fontsize = 10)
ax.text(dt.datetime(1980,1,1), -3.3,
"Dashed white lines refer to the first time Yield Curve inverts within
that period",
        fontsize = 10)

plt.savefig("fed_funds.png", bbox_inches = "tight", dip = 3000)

plt.show()
```



Above we can see that the Effective Federal Funds Rate drops after the inversions, even the 1998 in this case, which is what was bound to happen. The Federal Reserve performs Open Market Operations to lower this rate so that more credit is available, thus, stimulating the economy.

1982 Inversion

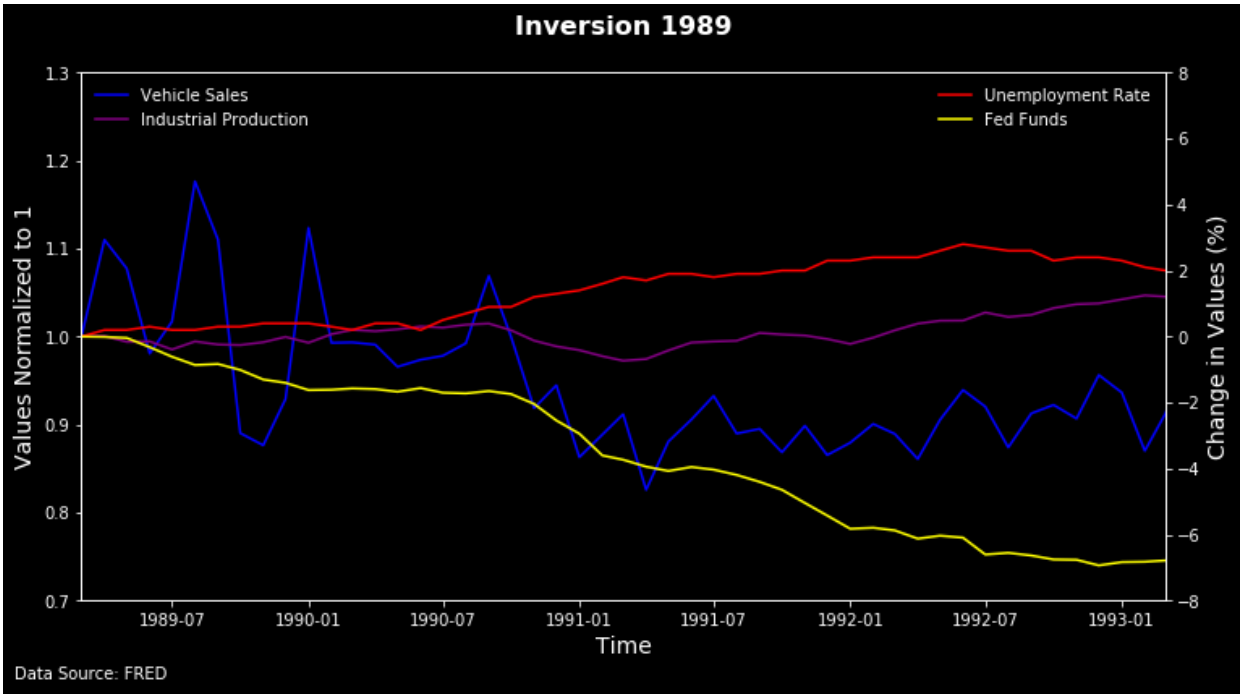
In [29]:
```
fig, ax1 = plt.subplots(figsize=(12,6))

ax1.plot(inversion_1982.index, inversion_1982['Vehicle_Sales'],
        color = 'blue', label = 'Vehicle Sales', alpha = 1)
ax1.plot(inversion_1982.index, inversion_1982['Industrial_Production']
,
        color = 'purple', label = 'Industrial Production', alpha = 1)

ax1.set_ylabel("Values Normalized to 1", fontsize = 14,)
ax1.legend(frameon=False, loc = 'upper left')
ax1.set_xlabel("Time", fontsize = 14,)
ax1.set_ylim(0.6,1.4)

ax2 = ax1.twinx()

ax2.plot(inversion_1982.index, inversion_1982['Unemployment_Rate'],
        color = 'red', label = 'Unemployment Rate', alpha = 1)
ax2.plot(inversion_1982.index, inversion_1982['Fed_Funds'],
        color = 'yellow', label = 'Fed Funds', alpha = 1)

ax2.set_title('Inversion 1982\n', fontsize = 16, fontweight = "bold")
ax2.set_ylabel("Change in Values (%)", fontsize = 14,)
ax2.set_xlim(dt.datetime(1982,2,1), dt.datetime(1983, 12, 31))
ax2.set_ylim(-8,8)
ax2.legend(frameon=False)

ax1.text(dt.datetime(1981,12,15), 0.475, "Data Source: FRED", fontsize
= 10)

plt.savefig("inversion_1982.png", bbox_inches = "tight", dip = 3000)

plt.show()
```



As shown, the 1982 inversion was followed by a period of moderate economic setbacks. In particular, we see a big drop in the Fed Funds Rate and a normal increase in the Unemployment Rate. However, Vehicle Sales actually pick up, something we also saw in the U.S. Vehicle Sales plot, and Industrial Production only drops slightly before eventually rising.

1989 Inversion

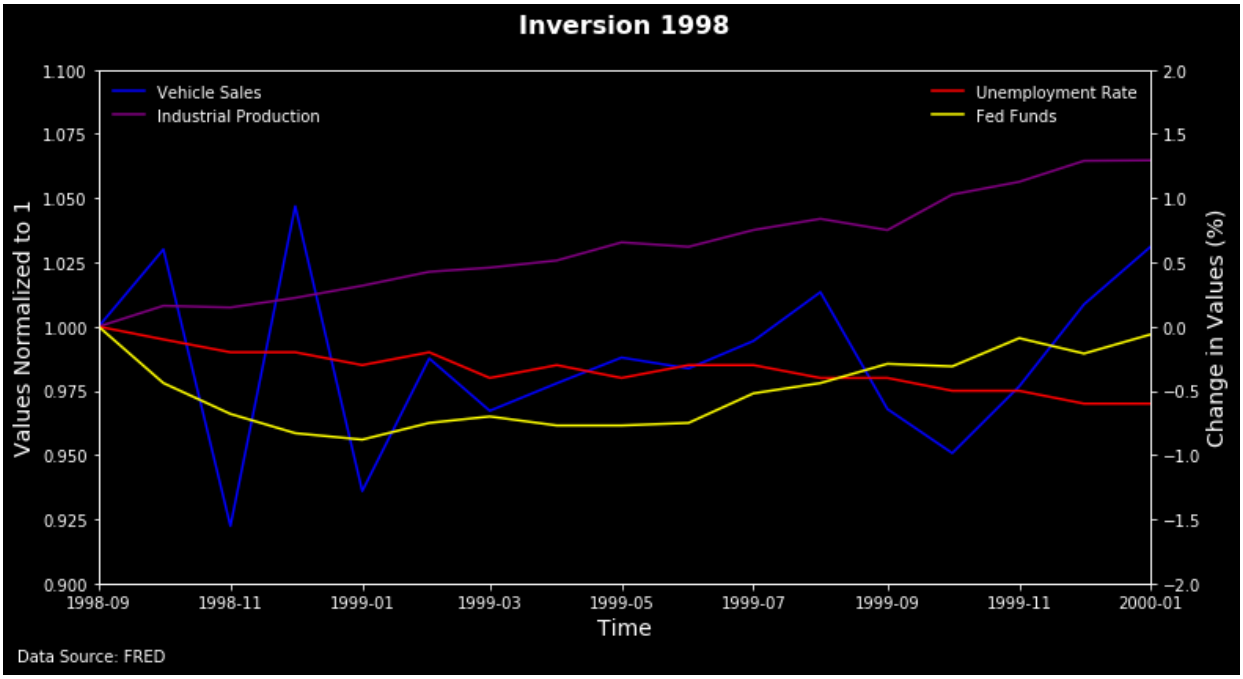
In [30]:
```
fig, ax1 = plt.subplots(figsize=(12,6))

ax1.plot(inversion_1989.index, inversion_1989['Vehicle_Sales'],
        color = 'blue', label = 'Vehicle Sales', alpha = 1)
ax1.plot(inversion_1989.index, inversion_1989['Industrial_Production']
,
        color = 'purple', label = 'Industrial Production', alpha = 1)

ax1.set_ylabel("Values Normalized to 1", fontsize = 14,)
ax1.legend(frameon=False, loc = 'upper left')
ax1.set_xlabel("Time", fontsize = 14,)
ax1.set_ylim(0.7,1.3)

ax2 = ax1.twinx()

ax2.plot(inversion_1989.index, inversion_1989['Unemployment_Rate'],
        color = 'red', label = 'Unemployment Rate', alpha = 1)
ax2.plot(inversion_1989.index, inversion_1989['Fed_Funds'],
        color = 'yellow', label = 'Fed Funds', alpha = 1)

ax2.set_title('Inversion 1989\n', fontsize = 16, fontweight = "bold")
ax2.set_ylabel("Change in Values (%)", fontsize = 14,)
ax2.set_xlim(dt.datetime(1989,3,1), dt.datetime(1993, 3, 1))
ax2.set_ylim(-8,8)
ax2.legend(frameon=False)

ax1.text(dt.datetime(1988,12,1), 0.611, "Data Source: FRED", fontsize
= 10)

plt.savefig("inversion_1989.png", bbox_inches = "tight", dip = 3000)

plt.show()
```



As showed by the graph above, the 1989 inversion was followed by a slight recession. There is a homogenous decrease in Vehicle Sales, Industrial Production, and the Fed Funds, while Unemployment rose.

1998 Inversion

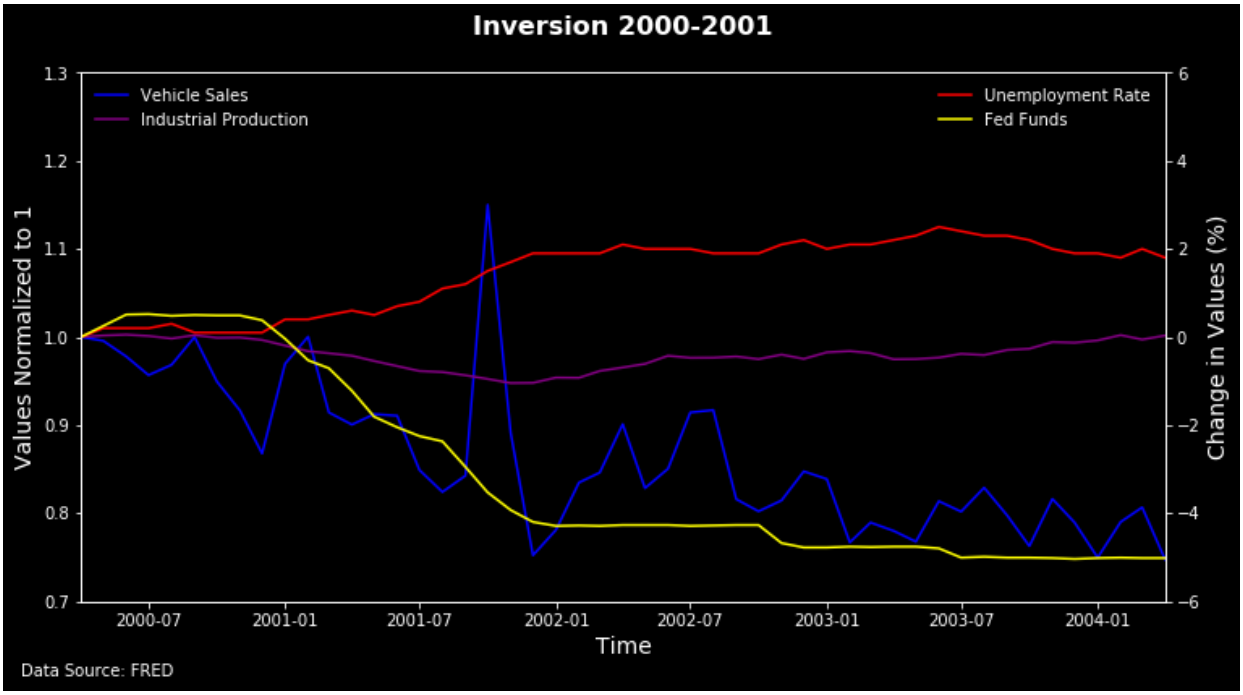
In [31]:
```
fig, ax1 = plt.subplots(figsize=(12,6))

ax1.plot(inversion_1998.index, inversion_1998['Vehicle_Sales'],
        color = 'blue', label = 'Vehicle Sales', alpha = 1)
ax1.plot(inversion_1998.index, inversion_1998['Industrial_Production']
,
        color = 'purple', label = 'Industrial Production', alpha = 1)

ax1.set_ylabel("Values Normalized to 1", fontsize = 14,)
ax1.legend(frameon=False, loc = 'upper left')
ax1.set_xlabel("Time", fontsize = 14,)
ax1.set_ylim(.9,1.1)

ax2 = ax1.twinx()

ax2.plot(inversion_1998.index, inversion_1998['Unemployment_Rate'],
        color = 'red', label = 'Unemployment Rate', alpha = 1)
ax2.plot(inversion_1998.index, inversion_1998['Fed_Funds'],
        color = 'yellow', label = 'Fed Funds', alpha = 1)

ax2.set_title('Inversion 1998\n', fontsize = 16, fontweight = "bold")
ax2.set_ylabel("Change in Values (%)", fontsize = 14,)
ax2.set_xlim(dt.datetime(1998,9,1), dt.datetime(2000, 1, 1))
ax2.set_ylim(-2,2)
ax2.legend(frameon=False)

ax1.text(dt.datetime(1998,7,25), .87, "Data Source: FRED", fontsize =
10)

plt.savefig("inversion_1998.png", bbox_inches = "tight", dip = 3000)

plt.show()
```



As we can see above, the inversion in 1998 did not have any significant effect in the economy. This is in line with what the plots of the individual economic indicators showed. The only indicator that showed a small sign of an economic decline was the Fed Funds, but even this was minimal (less than a -1% change).

2000-2001 Inversion

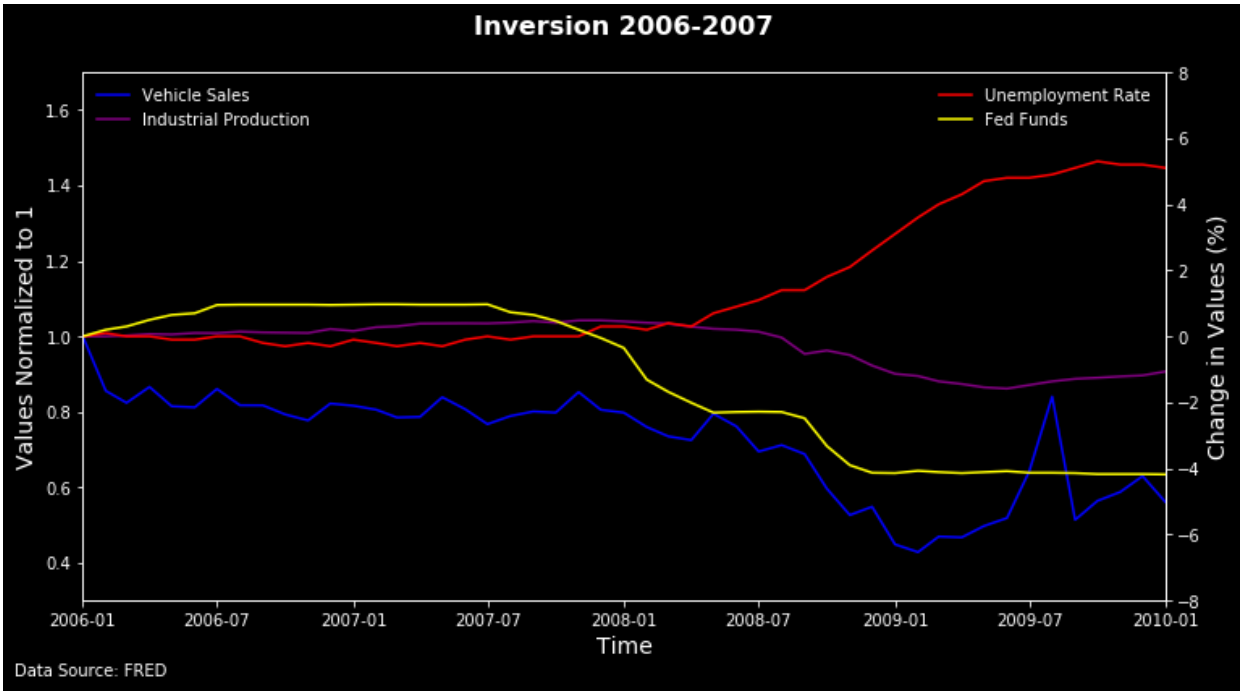
In [32]:
```
fig, ax1 = plt.subplots(figsize=(12,6))

ax1.plot(inversion_2000.index, inversion_2000['Vehicle_Sales'],
        color = 'blue', label = 'Vehicle Sales', alpha = 1)
ax1.plot(inversion_2000.index, inversion_2000['Industrial_Production']
,
        color = 'purple', label = 'Industrial Production', alpha = 1)

ax1.set_ylabel("Values Normalized to 1", fontsize = 14,)
ax1.legend(frameon=False, loc = 'upper left')
ax1.set_xlabel("Time", fontsize = 14,)
ax1.set_ylim(.7,1.3)

ax2 = ax1.twinx()

ax2.plot(inversion_2000.index, inversion_2000['Unemployment_Rate'],
        color = 'red', label = 'Unemployment Rate', alpha = 1)
ax2.plot(inversion_2000.index, inversion_2000['Fed_Funds'],
        color = 'yellow', label = 'Fed Funds', alpha = 1)

ax2.set_title('Inversion 2000-2001\n', fontsize = 16, fontweight = "bo
ld")
ax2.set_ylabel("Change in Values (%)", fontsize = 14,)
ax2.set_xlim(dt.datetime(2000,4,1), dt.datetime(2004, 4, 1))
ax2.set_ylim(-6,6)
ax2.legend(frameon=False)

ax1.text(dt.datetime(2000,1,10), .615, "Data Source: FRED", fontsize =
10)

plt.savefig("inversion_2000.png", bbox_inches = "tight", dip = 3000)

plt.show()
```



The inversion of 2000-2001, as shown above, was followed by a moderate period of economic decline. This period is commonly referred to as the Dotcom bust which was preceded by the Dotcom bubble. The same three indicators which are expected to drop during a recession, dropped and the Unemployment Rate rose due to a large amount of layoffs.

2006-2007 Inversion

In [33]:
```
fig, ax1 = plt.subplots(figsize=(12,6))

ax1.plot(inversion_2006.index, inversion_2006['Vehicle_Sales'],
        color = 'blue', label = 'Vehicle Sales', alpha = 1)
ax1.plot(inversion_2006.index, inversion_2006['Industrial_Production']
,
        color = 'purple', label = 'Industrial Production', alpha = 1)

ax1.set_ylabel("Values Normalized to 1", fontsize = 14,)
ax1.legend(frameon=False, loc = 'upper left')
ax1.set_xlabel("Time", fontsize = 14,)
ax1.set_ylim(0.3,1.7)

ax2 = ax1.twinx()

ax2.plot(inversion_2006.index, inversion_2006['Unemployment_Rate'],
        color = 'red', label = 'Unemployment Rate', alpha = 1)
ax2.plot(inversion_2006.index, inversion_2006['Fed_Funds'],
        color = 'yellow', label = 'Fed Funds', alpha = 1)

ax2.set_title('Inversion 2006-2007\n', fontsize = 16, fontweight = "bo
ld")
ax2.set_ylabel("Change in Values (%)", fontsize = 14,)
ax2.set_xlim(dt.datetime(2006,1,1), dt.datetime(2010, 1, 1))
ax2.set_ylim(-8,8)
ax2.legend(frameon=False)

ax1.text(dt.datetime(2005,10,1), .1, "Data Source: FRED", fontsize = 1
0)

plt.savefig("inversion_2006.png", bbox_inches = "tight", dip = 3000)

plt.show()
```

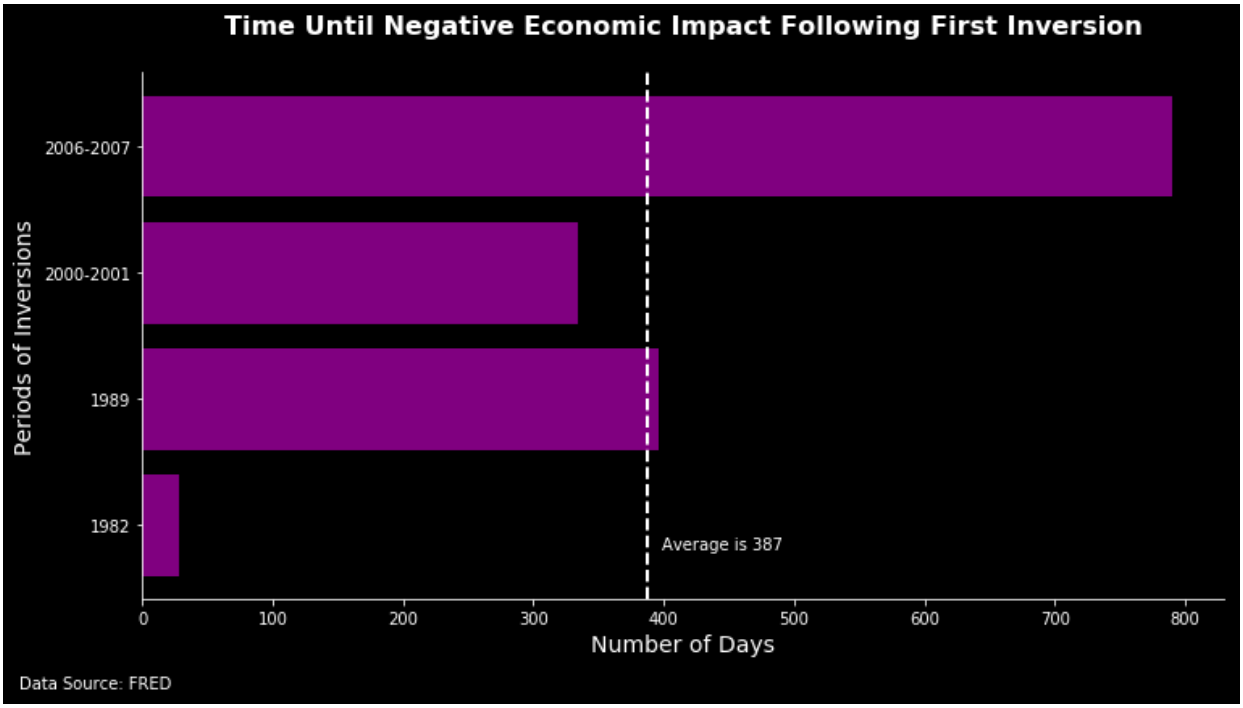


As shown above, the inversion in 2006-2007 was followed by one of the most drastic economic declines in U.S. history. This explains why the Unemployment Rate skyrocketed at such a steep angle and the Fed Funds Rate, Vehicle Sales, and Industrial Production steeply fell. Nothing less was expected of what became known as The Great Recession.

Time Delay

Now that the relationship between the Yield Curve and the U.S. economy has been established, it would be useful to determine how long it takes from the time the Curve inverts until the economy is affected. To do this, I will create a bar chart with the time it took all four economic indicator to experience a decline (or increase if Unemployment Rate) in growth after the first time an inversion in the Yield Curve occured for four out the five inversions.

In [35]:
```
fig, ax = plt.subplots(figsize=(12,6))

avg = time_delay.Days_Since_Inversion.mean()

ax.barh(time_delay.index, time_delay.Days_Since_Inversion, color = 'purple')

ax.set_title("Time Until Negative Economic Impact Following First Inversion\n",
             fontsize = '16', fontweight = 'bold')
ax.set_ylabel("Periods of Inversions", fontsize = '14')
ax.set_xlabel("Number of Days", fontsize = '14')

ax.text(-95, -1.3, "Data Source: FRED", fontsize = 10)

average = "Average is " + str(round(avg))
ax.text(avg + 12, -.2, average, horizontalalignment='left')

ax.spines["right"].set_visible(False)
ax.spines["top"].set_visible(False)

ax.axvline(x=avg, color='white', linestyle='--', linewidth=2)

plt.savefig("time_delay.png", bbox_inches = "tight", dip = 3000)

plt.show()
```



Conclusion

From looking at all the data there are three main takeaways. They are as follows:

1. The Yield Curve can indeed serve as a predictor of future economic crises. As we saw four out of five times, the U.S. economy was faced with an economic crisis after the inversions.
2. 1998's Yield Curve inversion was not followed by a recession. Therefore, the relationship should nevertheless be taken with a grain of salt.
3. From the first time the Curve inverts, it takes 387 days on average for the Unemployment Rate, Vehicle Sales, Industrial Production, and the Effective Funds Rate to all simultaneously indicate an economic decline.

With this I conclude and thank Professor Waugh for the guidance on this project as well as FRED for publishing the data used.

Bibliography

Federal Reserve Bank of St. Louis, 10-Year Treasury Constant Maturity Minus 3-Month Treasury Constant Maturity [T10Y3M], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/T10Y3M (https://fred.stlouisfed.org/series/T10Y3M), May 20, 2019.

U.S. Bureau of Labor Statistics, Civilian Unemployment Rate [UNRATE], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/UNRATE (https://fred.stlouisfed.org/series/UNRATE), May 20, 2019.

U.S. Bureau of Economic Analysis, Motor Vehicle Retail Sales: Domestic Autos [DAUTOSA], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/DAUTOSA (https://fred.stlouisfed.org/series/DAUTOSA), May 20, 2019.

Board of Governors of the Federal Reserve System (US), Industrial Production Index [INDPRO], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/INDPRO (https://fred.stlouisfed.org/series/INDPRO), May 20, 2019.

Board of Governors of the Federal Reserve System (US), Effective Federal Funds Rate [FEDFUNDS], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/FEDFUNDS (https://fred.stlouisfed.org/series/FEDFUNDS), May 20, 2019.